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LIGHTING DATA

EDISON LAMP WORKS

OF GENERAL ELECTRIC COMPANY

GENERAL SALES OFFICE HARRISON, N. J.

The Incandescent Lamp—Its History

Information compiled by

HENRY SCHROEDER

Commercial Engineering Department

SYNOPSIS:

For information regarding MAZDA lamps and lighting questions, refer to the nearest sales office.

To make sure that you receive all bulletins, notify the Department of Publicity, Edison Lamp Works of General Electric Company, Harrison, N. J., of any change of address.

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Invention of the Battery

In 1800 Alexander Volta, an Italian physicist, demonstrated his discovery that electricity could be generated by chemical means. He made a pile of silver and zinc discs with cloths, wet with salt water, between them. This is the principle of the present day primary battery and the so-called dry cells which are sealed up for convenience. This was the first time that a continuous supply of electricity was made obtainable, and the VOLT, the unit of electrical pressure, was named in his honor.

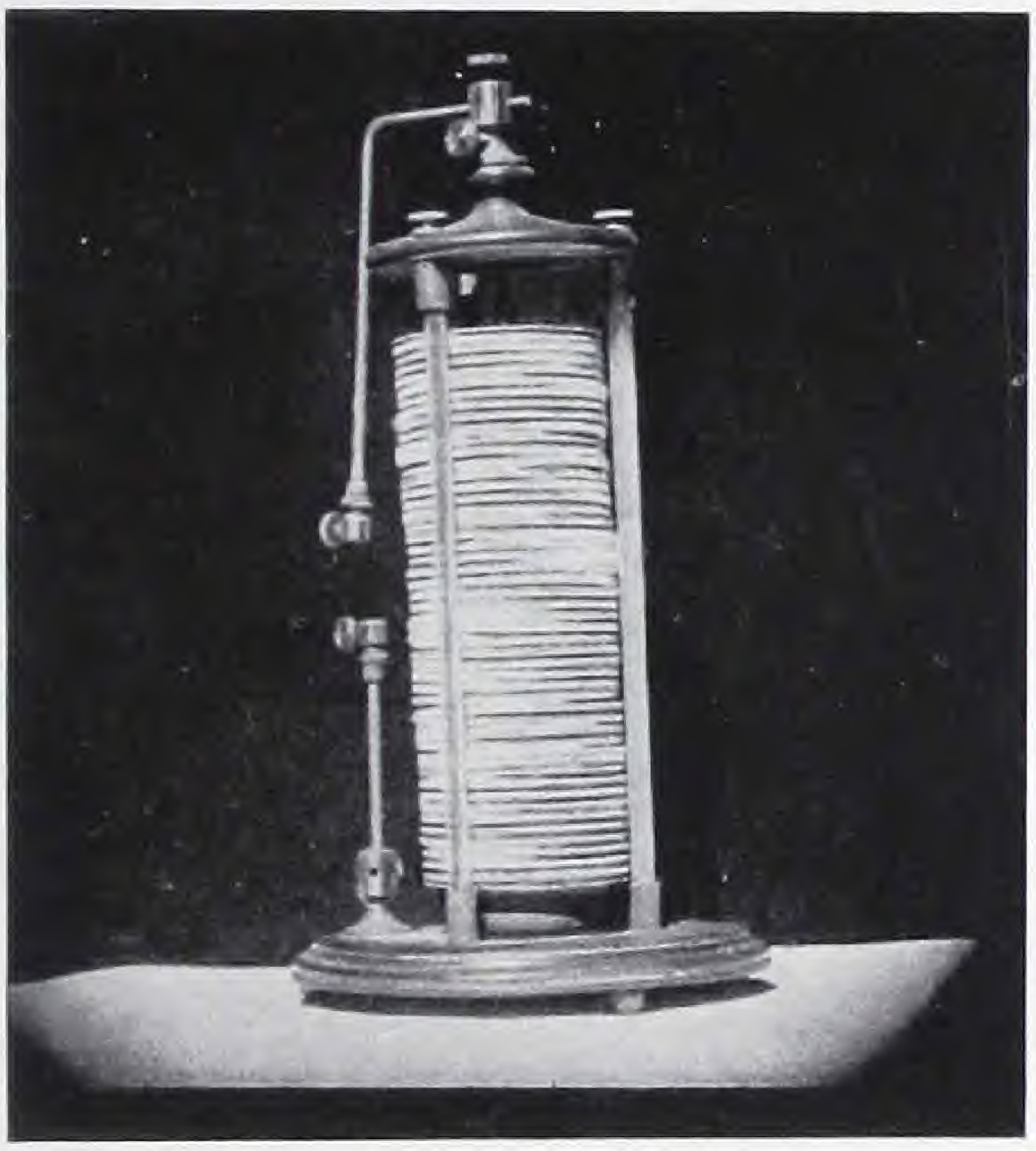

FIG. 1
Voltaic Pile. The First Battery

Sir Humphry Davy, the well known English scientist, improved the voltaic pile by the use of zinc and copper plates in dilute sulphuric acid. He read a number of papers before the Royal Society in London during the years 1802 to 1827, on the chemical effects of electricity. Incidentally he demonstrated the arc and that electricity could be made to heat metals to incandescence. Platinum was the only metal that would stay incandescent without quickly oxidizing, but the cost of electric current was so enormous (six dollars a minute to demonstrate the arc) that no one then seriously thought of making an electric lamp.

Invention of the Dynamo

Michael Faraday, another Englishman, in 1831 demonstrated that electricity could be generated by means of a magnet. He made a machine consisting of a twelve-inch copper disc which rotated between the poles of a permanent magnet, the current generated being collected by wires connected to the hub and to a brush rubbing the periphery of the disc.

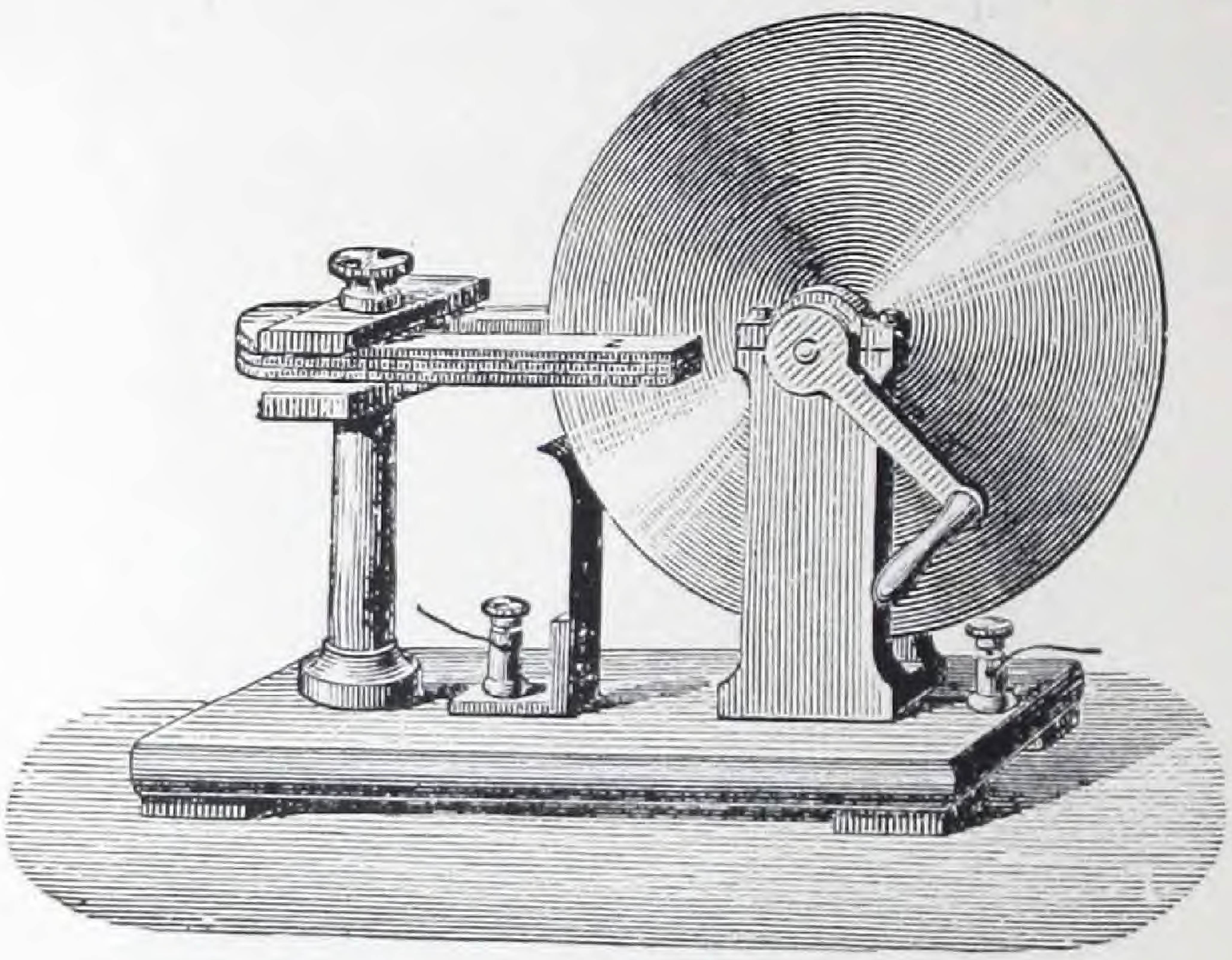

Fig. 2
Faraday's Dynamo

The next year, Hippolyte Pixii, a Frenchman, made a machine in which a permanent horseshoe magnet revolved in front of two wire bobbins mounted on a soft iron core. Two years later (1834) E. M. Clarke, an Englishman, made a machine in which the bobbins revolved in front of the magnet poles.

During the next few years several inventors improved the dynamo. Woolrich increased the number of bobbins to make the current less pulsating, Wheatstone used electro magnets and Pulvermacher used thin plates of iron to reduce the eddy currents in the iron. The dynamo was still a laboratory machine, but it was possible to obtain electricity at much less expense.

Early Incandescent Lamp Investigators

Platinum had to be operated very close to its melting temperature before it gave any light. Other substances would rapidly oxidize at the high temperatures required for incandescence. Carbon quickly burned up but gave a brilliant light as shown by the arc. However, if dense thick rods were used for the arc, they could be made to last a few hours.

Some inventors tried to make an incandescent lamp. The first patent was granted to an Englishman, Frederick De Moleyns in 1841 (English patent No. 9053, August 21, 1841). This lamp con-

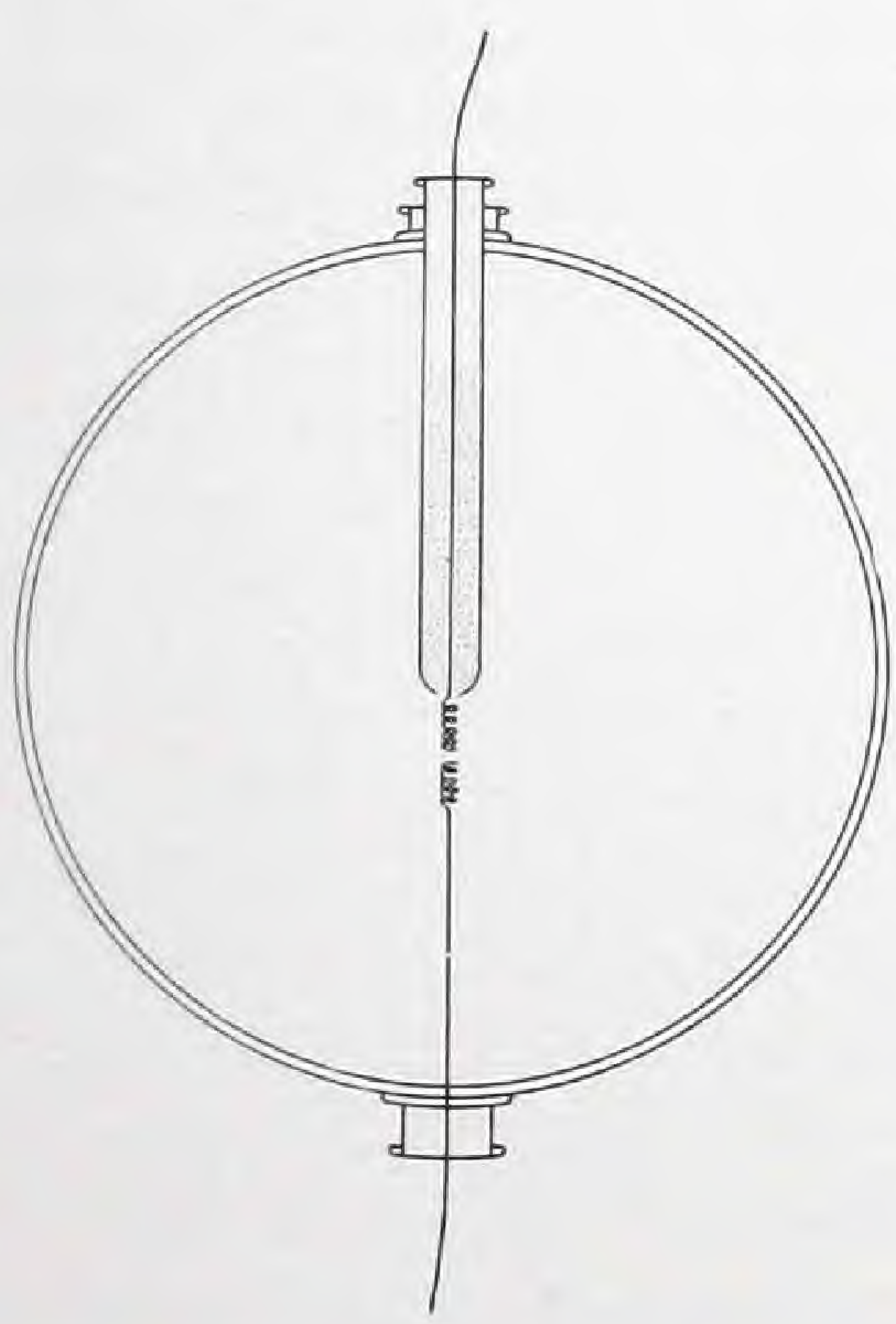

FIG. 3
De Moleyns' Lamp

FIG. 4
Starr's Lamp

sisted of a spherical glass globe within which was a tube, open at the bottom, containing powdered charcoal. A platinum wire was inserted through the tube, the end below the tube being coiled. Another platinum wire, also coiled at the end, came up from the bottom of the sphere but did not quite touch the first. The powdered charcoal filled the two coils of platinum wire and bridged the gap between. Current passing through this charcoal bridge heated it to incandescence. The air in the glass globe having been removed as far as was possible with the hand air pumps then available, the charcoal did not burn up at once, the small amount consumed being replaced by the supply in the tube. The idea was ingenious, but the lamp was impractical as the globe rapidly blackened from the evaporation of the incandescent charcoal.

In 1845, J. W. Starr of Cincinnati, Ohio, invented a lamp for which he received a British patent (No. 10,919, Nov. 4, 1845) although it was taken out under the name of King, his English patent attorney. This consisted of a rod of carbon operating in the vacuum above a column of mercury. This lamp also blackened rapidly and hence was impractical.

Other early investigators were William Greener, William E. Staite, Professor J. W. Draper, Edward C. Shepard, M. J. Roberts, C. de Changy and Professor Moses G. Farmer. The lamps they made consisted of either platinum or iridium operating in air but covered by a globe to protect the burner from draughts, or of carbon or graphite in the poor vacuum then obtainable. None were more than laboratory experiments, although patents were granted on many of them.

Arc Lighting

During the ten years 1860 to 1870 scientists turned their attention to the arc lamp. Mechanisms had been invented to maintain the arc lamp carbons the proper distance apart as fast as they were consumed. The first commercial installation of an electric light, an arc lamp, was in the Dungeness lighthouse in England by the Alliance Company. This was started in 1858 but the installation was not formally accepted until 1862. The dynamo used consisted of a large number of stationary permanent magnets in front of which a great many wire bobbins, mounted on a shaft, were rotated. The machine had collector rings and generated alternating current to overcome the difficulties of commutation. The next year, 1863, several arc lights were installed in French lighthouses.

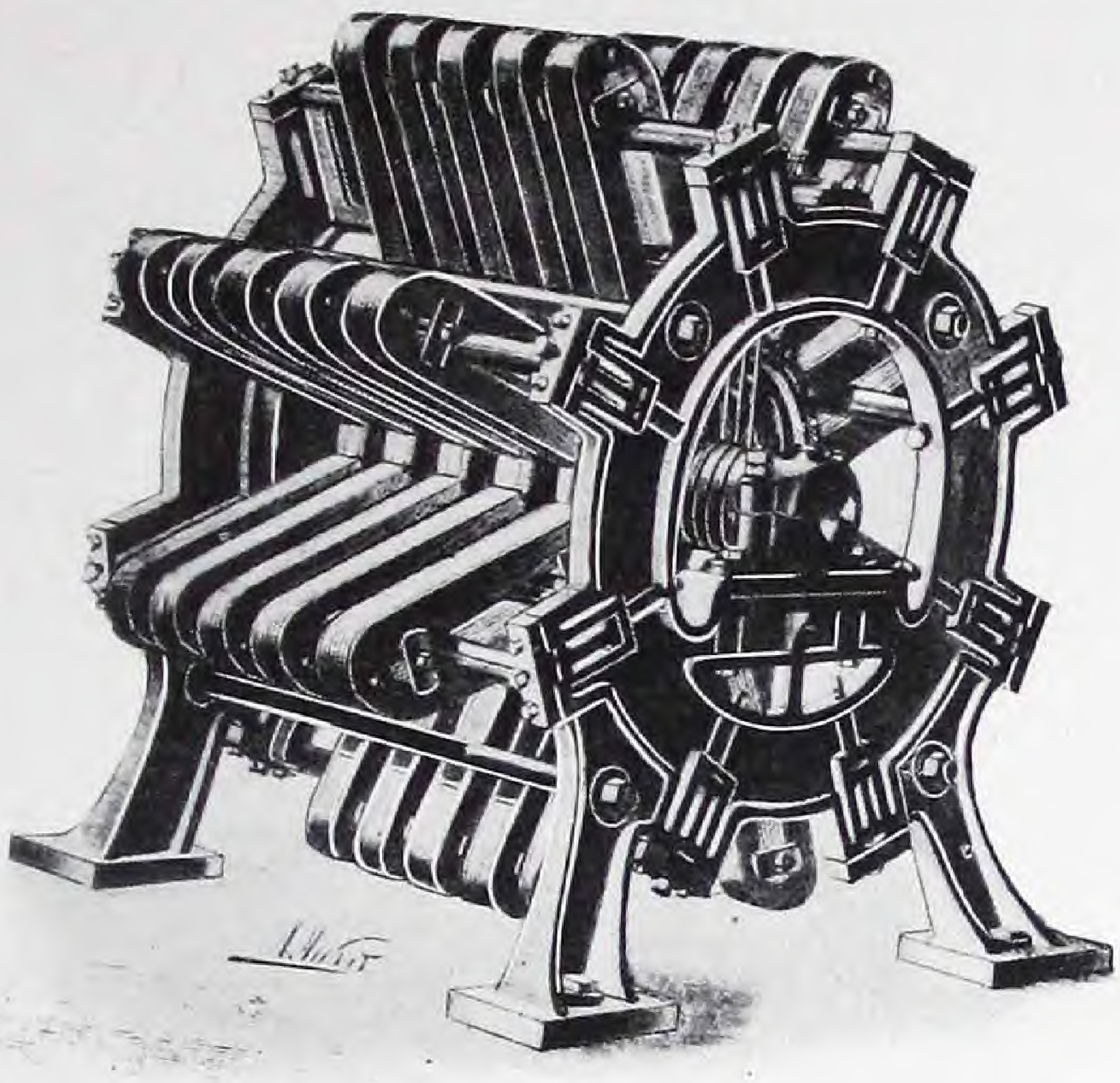

FIG. 5
Alliance Dynamo

It is interesting to note that this dynamo had been invented in 1850 by Nollet, a professor of physics at Brussels, and had then a commutator so as to obtain direct current. A company was formed to sell hydrogen gas for illuminating purposes, the gas to be made by the decomposition of water with current from this machine. Nollet died and the company failed but it was reorganized a few years later to exploit the arc lamp.

Improvements in the Dynamo

By 1870 the dynamo began to emerge from the laboratory stage. Dr. Werner Siemens had invented the shuttle wound armature in 1856. Sir Charles Wheatstone in 1866 made a self-excited machine by use of the residual magnetism in the field poles, which was almost simultaneously invented by Dr. Siemens. Gramme in 1870 patented the ring wound armature and developed it into commercial form. This principle, however, had been invented by Pacinnotti in 1860 in a motor he had devised. Hefner-Alteneck in 1872 invented the drum wound, or so-called Siemens, armature.

Later Incandescent Lamp Investigators

Lodyguine, a Russian scientist, made an incandescent lamp consisting of a piece of graphite operating in nitrogen gas. In 1872 he lighted the Admiralty Dockyard at St. Petersburg with two hundred

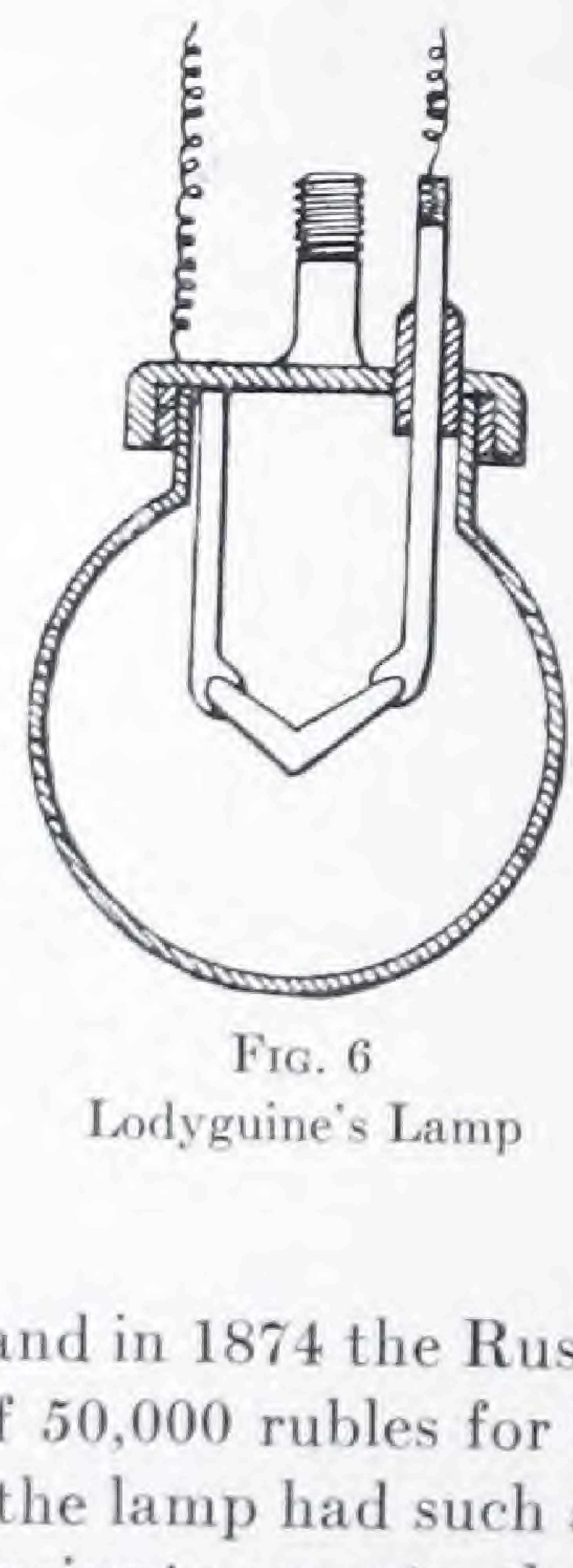

FIG. 6
Lodyguine's Lamp

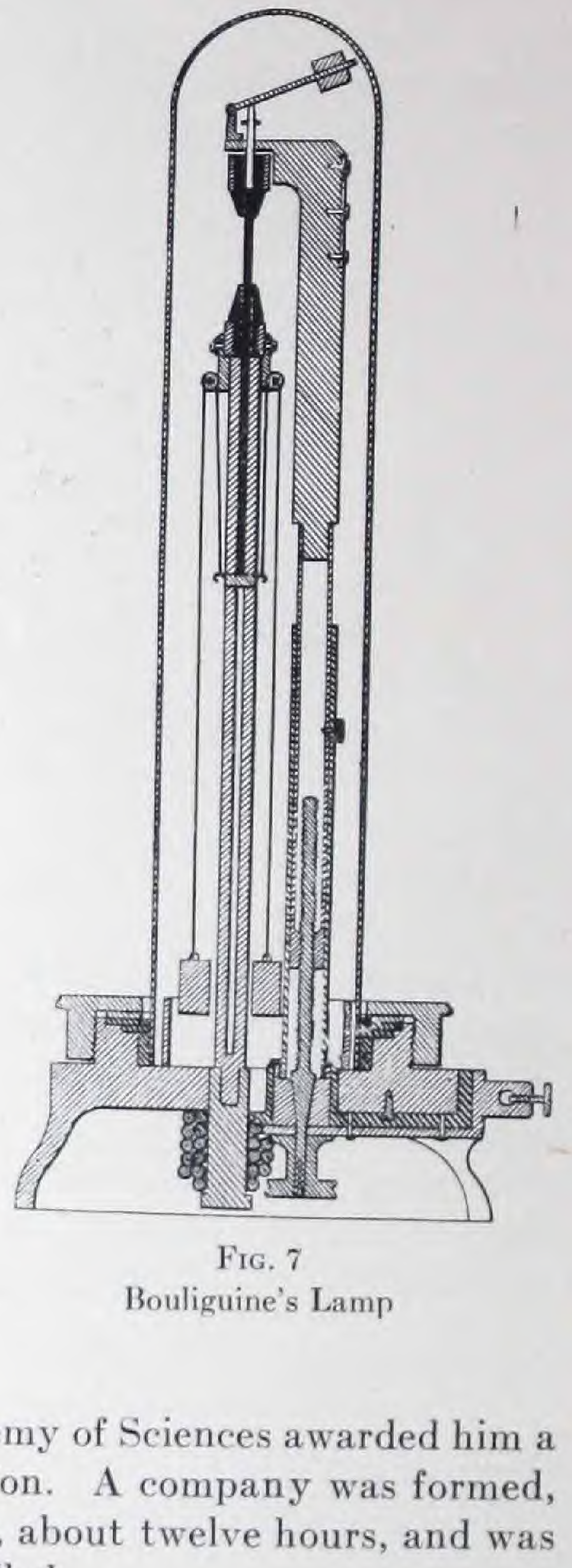

FIG. 7
Bouliguine's Lamp

lamps and in 1874 the Russian Academy of Sciences awarded him a prize of 50,000 rubles for his invention. A company was formed, but as the lamp had such a short life, about twelve hours, and was so expensive to operate, the project failed.

Kosloff, another Russian, improved the lamp by having several graphite rods so arranged that when one rod burned out another was automatically connected. This was in 1874, and the next year, Konn, also Russian, tried the same idea but operated the graphite rods in vacuum. The following year, 1876, Bouliguine made a vacuum lamp with a single long graphite rod, the upper part of which only was in circuit. As this part burned out, the rod was automatically shoved up by a counterweight, so that a new portion of the rod was used. None of these lamps was a commercial success.

Commercial Establishment of the Arc Lamp

In 1876 Jablockoff had developed his "electric candle." This was an arc light and consisted of two carbon rods side by side but insulated from each other by kaolin. Alternating current was used so that both rods were consumed at the same rate. The device was very simple, requiring no mechanism, and several boulevards in Paris were equipped with these lamps.

Fig. 8
Edison's Menlo Park Buildings

In this country William Wallace with Prof. Moses G. Farmer, Charles F. Brush and Edward Weston invented complete systems of arc lamps and dynamos. By 1878 the arc lamp was commercially established, being used for street lighting.

The arc lamp was too large a unit for houshold use, so scientists all over the world became interested in the problem of "subdividing the electric light" as it was called. In this country there were several men engaged in this work, among whom were Hiram S. Maxim, William E. Sawyer, Prof. Moses G. Farmer and Thomas A. Edison.

Sawyer and Farmer worked along the lines of the Russian scientists by endeavoring to operate a carbon rod in nitrogen gas and Maxim a carbon rod in vacuum and sheet platinum in air.

Edison's Experimental Work and Study

Edison, who finally solved the problem, had a well equipped laboratory at Menlo Park, N. J., with several able assistants and a number of expert workmen, about 100 people all told. He had already made a number of well known inventions, among which were the quadruplex telegraph whereby four messages could be sent simultaneously over one wire, the carbon telephone transmitter without which Bell's telephone receiver would have been impractical, and the phonograph. All these inventions are in use today. Edison was backed by a $100,000 corporation, the Edison Electric Light Company, organized October 16, 1878, by some prominent men for the purpose of developing an incandescent electric lighting system.

FIG. 9
Exterior of Edison's Laboratory

Edison first tackled the problem in the spring of 1878, making many experiments to confirm the failures previously made by others. In the summer, his health having been undermined by his unceasing work, he took a trip out West for a "vacation." He went with an expedition to Wyoming to observe an eclipse of the sun, and in-

cidentally to test his tasimeter, a delicate instrument devised by him for measuring heat transmitted through great distances.

On returning about two months later, he again studied the lamp problem. His first experiments having shown the seeming impracticability of carbon for a light giving element, he began experimenting with platinum. Finding that platinum had to be operated very close to the melting temperature to give any light, and in order to prevent the burner from getting too hot and melting, he

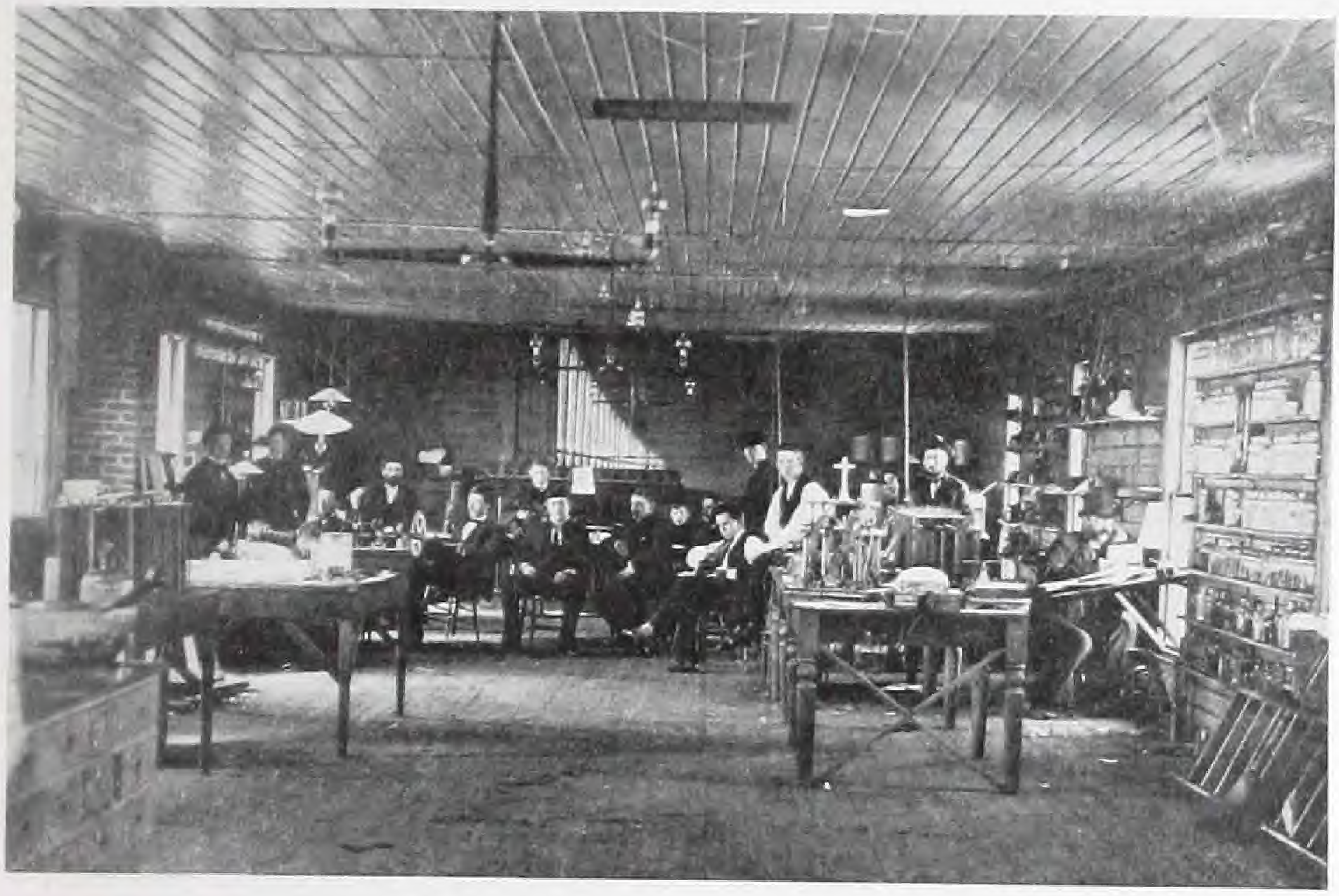

Fig. 10
Interior of Edison's Laboratory

developed a thermostatic regulator. When the temperature became too high, a rod expanded, short circuiting the burner until it cooled again. He also discovered that by gradually heating the platinum burner, the occluded gases in the platinum were driven out so that it became exceedingly hard and could be operated at a much higher temperature without melting. This enabled him to construct a lamp that gave much more light than it otherwise would have given. He applied for a patent on this lamp on October 14, 1878, and his first lamp patent, No. 214,636, was granted April 22, 1879.

His next step was to make a more sensitive thermostat by use of an expanding diaphragm. A patent was applied for on November 18, 1878, and No. 214,637 was granted April 22, 1879. He then made a burner of sheet platinum for which he obtained a patent. He also

made a burner of oxide of zirconium impregnated with iridium and obtained a patent on this. Another patent was granted on a lamp consisting of a carbon rod pressing against a rod of platinum and iridium, the light being obtained from the heat generated from the resistance of the poor contact.

The only method of distributing electric current for arc lighting at that time was the series constant current system. This constant current was usually direct current although in a few cases constant

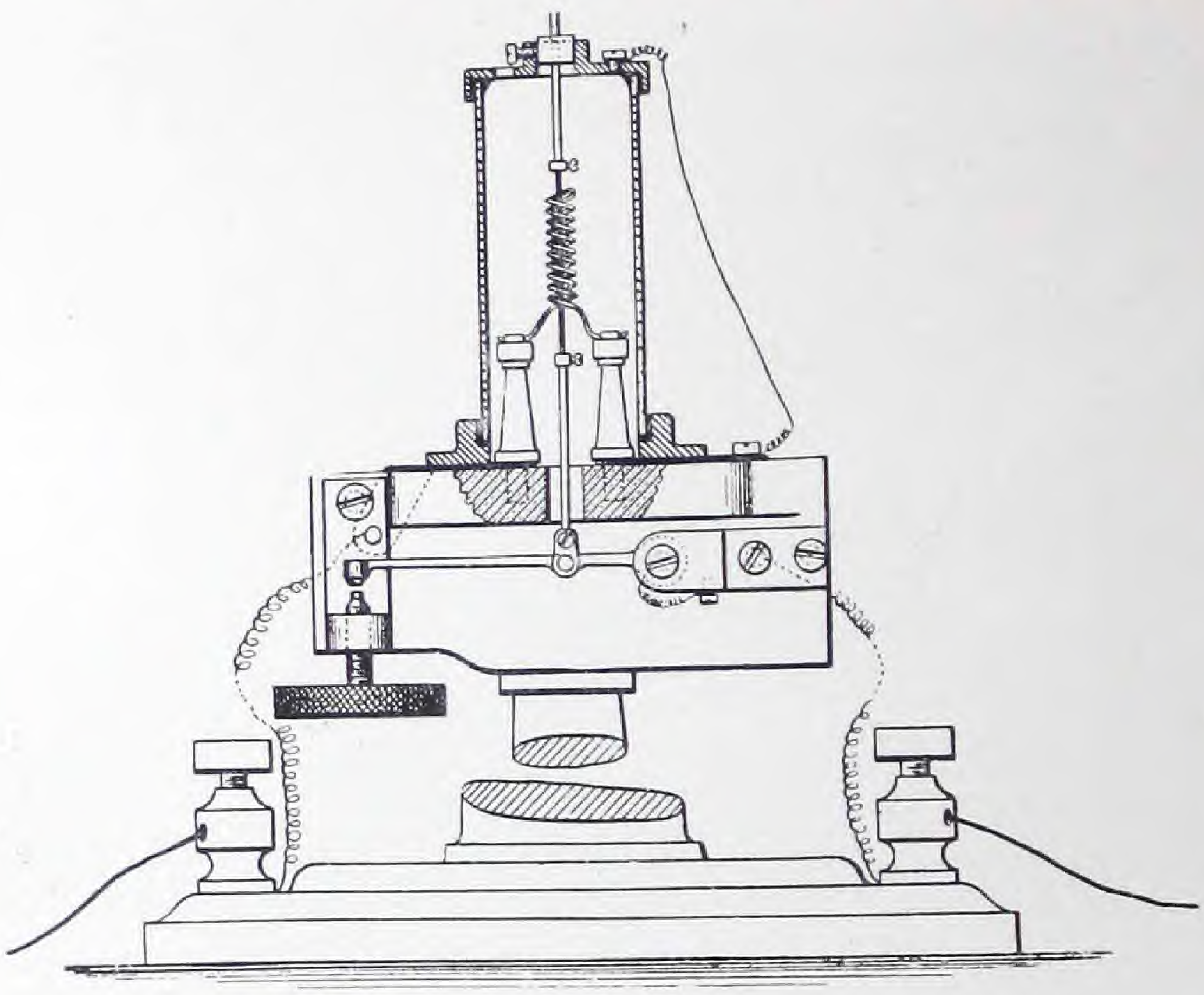

FIG. 11

Edison's Platinum Lamp on which He Received His First Lamp Patent

alternating current had been used. The arc lamp is inherently a constant current device. All incandescent lamps that had been made were designed for such a system. It was impossible then to light or extinguish one lamp at a time as the whole system had either to be completely on or off, such an arrangement being satisfactory for street lighting. Edison soon realized that each lamp, for household use, must be independent of every other, which would be possible only with a constant potential multiple system. Estimates of the cost of the distributing wires soon showed that the voltage must be relatively high to keep the cost within reason.

Previous lamps had required about ten amperes at about ten volts, but if they could be made for one ampere at a hundred volts they would consume the same amount of power (100 watts) as before. Thus if the amperes could be reduced one tenth, the distributing wires need be but one hundreth in size, as the power lost in the distributing wires varies as the square of the amperes (C^2R loss).

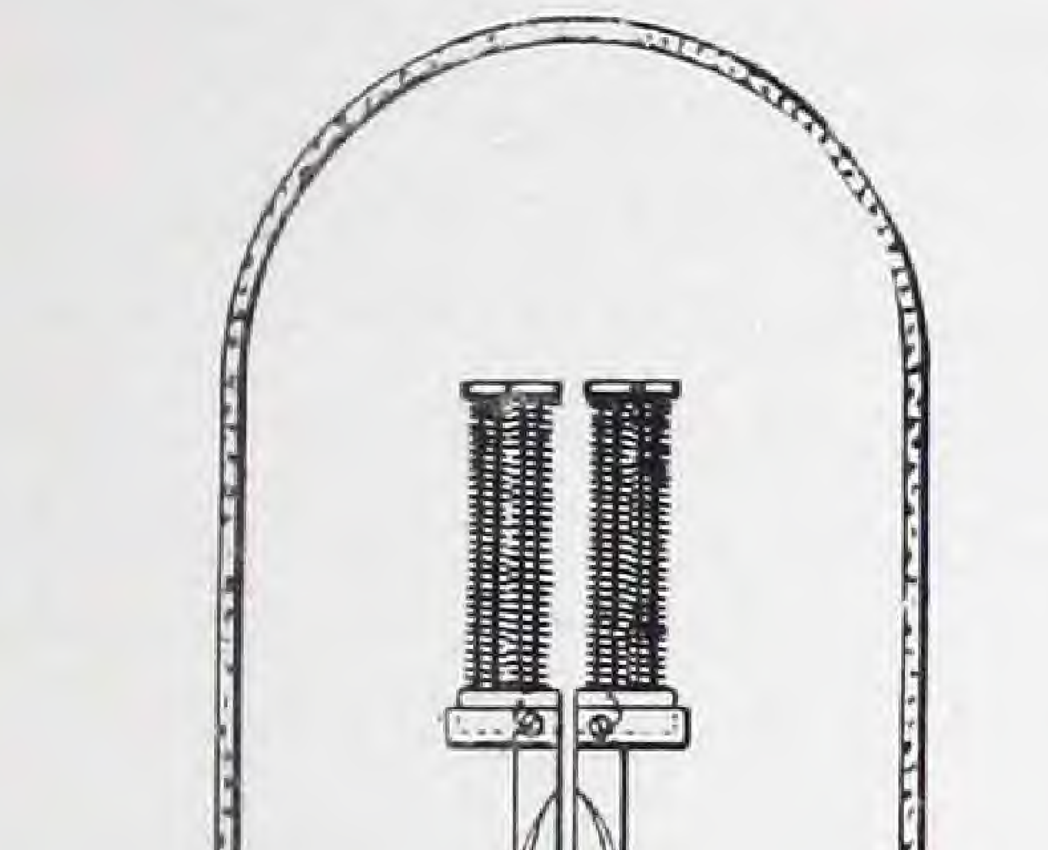

Fig. 12
Edison's High Resistance Platinum Lamp in Air

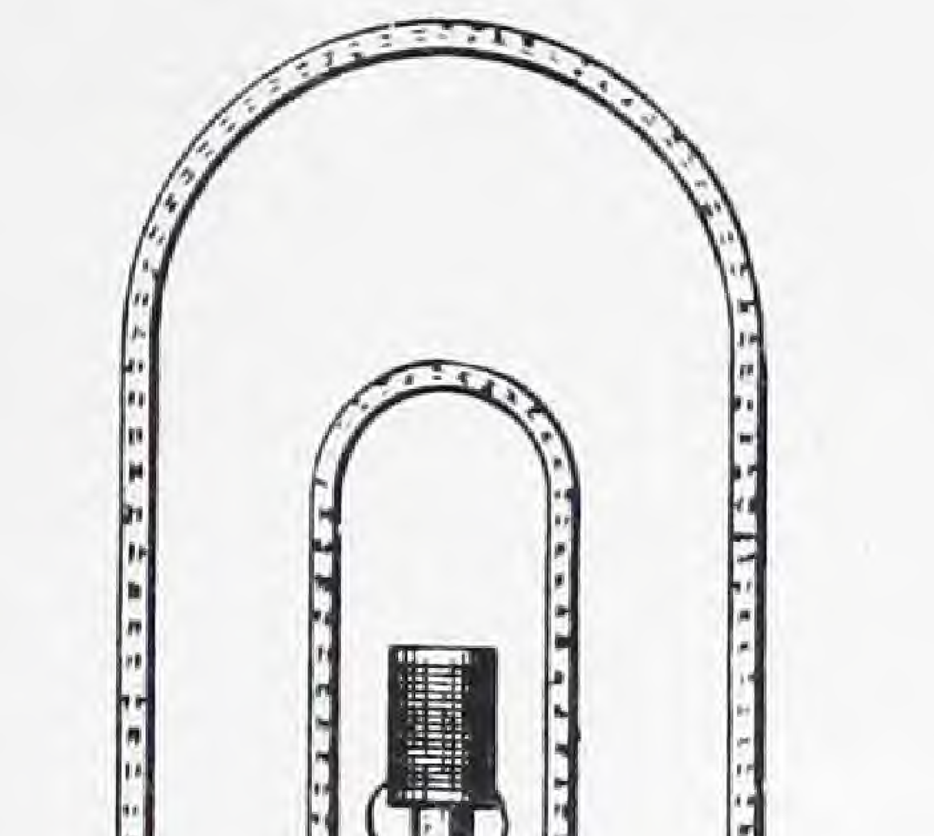

Fig. 13
Edison's High Resistance Platinum Lamp in Vacuum

The resistance of a 100-watt, 10-ampere 10-volt lamp would be one ohm, and of a 100-watt, 1-ampere 100-volt lamp would be one hundred ohms. Edison therefore reasoned he must have a high resistance lamp in order to have a practical multiple system of distribution.

Development of a High Resistance Lamp

Following up this line of reasoning, Edison wound many feet of fine platinum wire on a spool of pipe clay, and coated it with oxide of zirconium with the idea of retarding the evaporation of the platinum at the high temperature at which it operated. A patent was applied for on February 10, 1879, and granted May 4, 1880. This lamp was not a success as while oxide of zirconium at ordinary temperatures is an insulator, it becomes a conductor of electricity at high temperatures, so the lamp short circuited itself.

Knowing that he had made a different quality of platinum by gradually heating it, he thought he might be able to further harden it by heating it in vacuum to drive out still more of the occluded gases. The Geissler and Sprengel mercury air pumps, which had recently been invented, gave a much higher degree of vacuum than had heretofore been obtained. Realizing that nothing but an all glass globe could maintain the vacuum possible with such a pump, he mounted a spool of fine platinum wire in such a globe. The ends of the platinum wire passed through the glass and were made air tight by fusing the glass around the wires. He gradually heated the platinum by passing current through it while the globe was being exhausted. After sealing off the globe it was put inside a glass cover and the ends of the platinum wire were connected to the terminals of a diaphragm thermostatic switch. This prevented the platinum from melting by disconnecting it from the circuit when the temperature became too high. A patent was applied for on April 21, 1879, and granted May 4, 1880. This lamp appeared to have solved the problem, but it was very expensive to make.

Knowing that a long and very thin piece of carbon would give him the desired high resistance at much less cost and might last in the high vacuum he had obtained, he carbonized a piece of ordinary sewing thread by packing it in an airtight crucible and heating the crucible to a high temperature in a furnace. This drove off all the volatile material in the thread, leaving only the carbon behind in a manner similar to distilling coal in a closed retort, which leaves a coke residue behind. After several trials he finally mounted a carbonized thread in a one piece all glass globe, all joints being hermetically sealed by fusion. After exhausting it for some time, a slight current was passed through the carbonized thread to gently heat it. Immediately the occluded gases began to come out of the thread and it took about eight hours more on the exhaust pump before the gases stopped coming out. He then sealed the lamp.

FIG. 14
Edison's First Successful Lamp

This was October 21, 1879, and the lamp burned steadily day and night for 45 hours before it failed. A patent was applied for on November 4, 1879, and granted January 27, 1880. This patent, No. 223,898, is interesting as the general principle of making lamps is practically the same today, although enormous strides have been made since the first commercial lamps were sold. The patent was tested in the courts and after many years of litigation was finally upheld in the lower court in 1891 and sustained in the Appellate Court in 1892.

During the month of November, 1879, everything conceivable was carbonized to see if a better "filament," as Edison called it, could be obtained. Carbonized paper was found to give good results, the lamps lasting several hundred hours, so that the lamp then was considered to be a commercial possibility.

It was decided that a public exhibition of the lamp should be made, so wires were run to several houses in the neighorhood and to street lights on poles, about sixty lamps being installed. Announcement was made in the *New York Herald* of December 21, 1879, just three months after the "birth" of the lamp. This occupied the entire first reading matter page of the newspaper, and created such a furor that special trains had to be run by the Pennsylvania Railroad to Menlo Park during the Christmas holidays to accommodate the crowds.

Other Parts of the Complete Lighting System

Edison had to devise all the other necessary parts of the system to make it commercial as none of them had hitherto been made by others. He made a constant potential dynamo which had a very low resistance armature consisting of drum wound bars of copper revolving in a shunt field. He was thus able to get about 90 per cent efficiency, which had been claimed impossible by scientists. They argued that the internal resistance of the dynamo must be equal to the resistance of the outside circuit (the principle of the primary battery) in order to obtain the maximum possible efficiency of 50 per cent.

Fig. 15
Edison's Constant Potential Dynamo

Edison also invented the lead wire fuse to protect the dynamo from overload, an electrolytic meter to measure the current consumed, the socket, etc. He designed and made a network of underground conductors so that a practically constant voltage would be maintained throughout the system. The network was so arranged that current for any given area could be supplied from several different directions to insure reliability of service in case of trouble on any part of the system. The underground conductors had to be properly insulated which was considered impossible by many engineers at that time, and capable of being tapped whenever necessary, thus requiring a host of devices such as junction boxes, coupling and "T" boxes, service boxes, etc.

He also designed and made devices for regulating and equalizing the fluctuating load on each dynamo so that they could be interconnected, which heretofore had never been done. Thus in a short time he had developed a complete commercial lighting system, which was a great achievement, as there were no precedents to go by.

The First Commercial Installation

The first commercial marine installation was on the steamship *Columbia,* which was started on May 2, 1880. The ship was equipped with about 115 lamps and had three dynamos. One dynamo was used as an exciter for the fields of the other two.

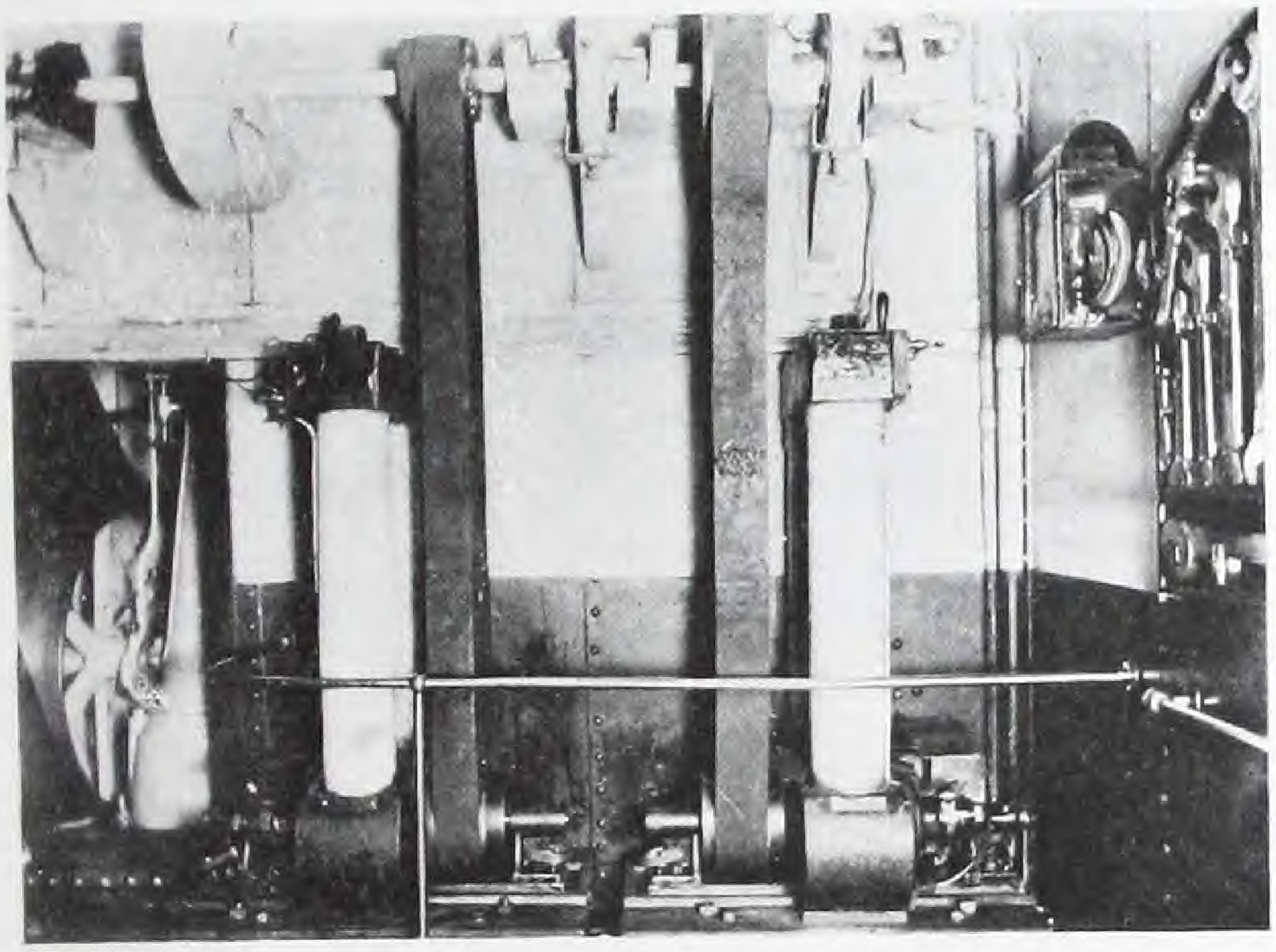

FIG. 16
Dynamos on S. S. *Columbia.* The first commercial installation

Each dynamo had a capacity for 60 lamps. After a trip around the Horn, the ship arrived in San Francisco in July, 1880, reporting that the lighting installation was an entire success.

Developments During 1880

Experiments to further improve the lamp were continued in 1880. The carbonized paper filaments were quite fragile. It was found that carbonized bamboo was not only sturdy but gave longer life and so was adopted for the filament. The shape of the

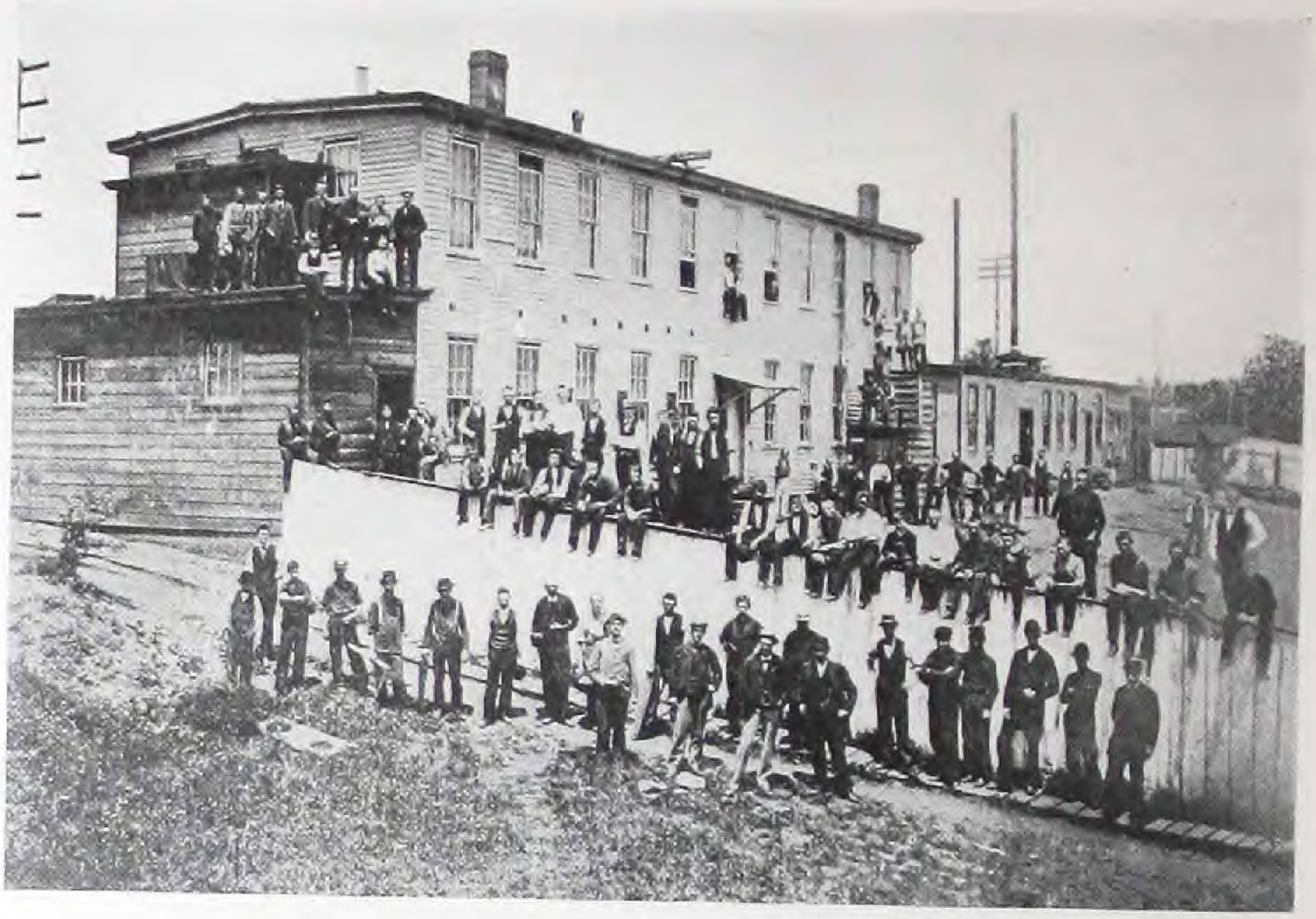

Fig. 17
The First Incandescent Lamp Factory

bulb was changed from round to pear shape, being blown from one inch tubing. Later the bulbs were blown direct from molten glass.

As it was inconvenient to connect the wires to the binding posts of a new lamp every time a burned out lamp had to be replaced, a

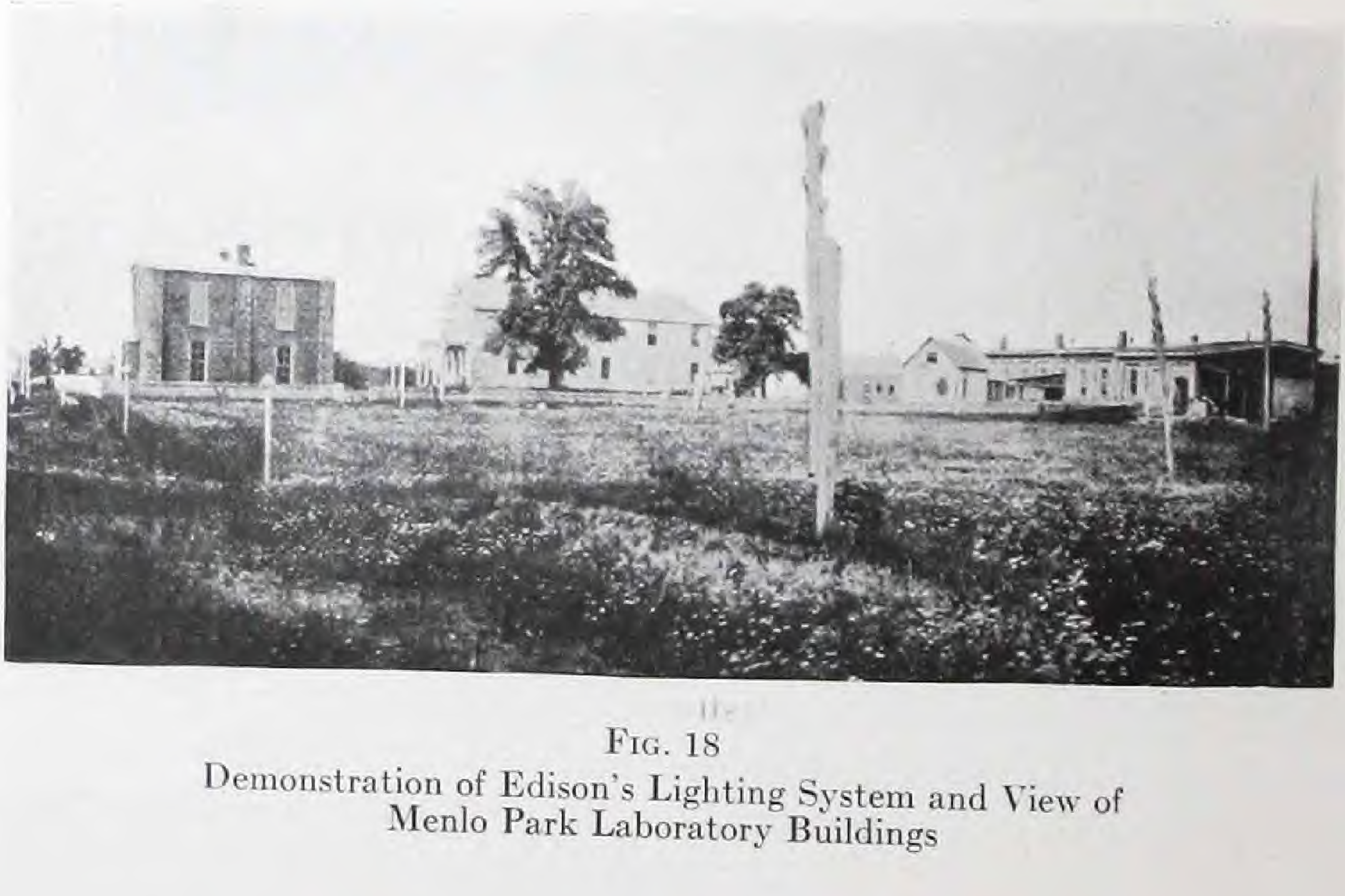

Fig. 18
Demonstration of Edison's Lighting System and View of Menlo Park Laboratory Buildings

base was developed. The terminals of the base consisted of a screw shell and a ring, wood being used for insulation.

A separate organization, the Edison Lamp Company, was formed to take over the manufacture of lamps. A factory building was obtained, located alongside the Pennsylvania Railroad tracks about half a mile from the laboratory, and the first lamp factory in the world was started in November, 1880.

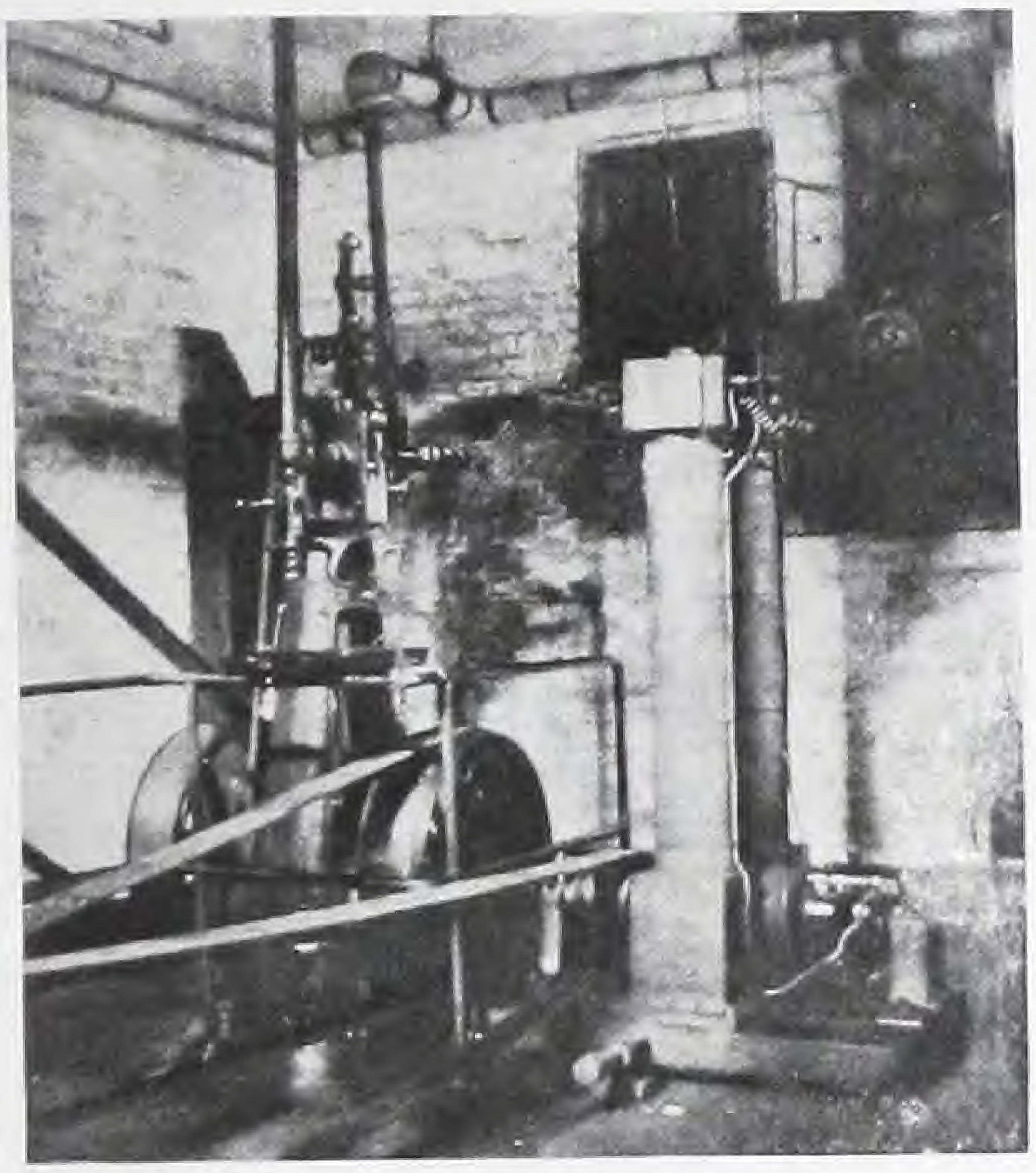

Fig. 19
Dynamo, Hinds Ketcham & Co.
(Photograph, courtesy U. S. National Museum, Washington, D. C.)

In December, 1880, another demonstration of Edison's electric incandescent lighting system was given, about 500 lamps being operated in a number of houses and for street lights, underground cable being used to distribute the current.

Developments During 1881

The second commercial installation, the first on land, was started in Hinds Ketcham & Company, lithographers, 229 Pearl St., New York, about the first of the year 1881. About one hundred sockets were installed. Several other installations were made throughout the Eastern States, so that by the end of the year the incandescent lamp was commercially established.

Early in the year, the shape of the base was changed, the terminals of the base consisting of a cone shaped ring and a screw

shell, wood being used for insulation. As plaster of paris was used to fasten the base to the buib, this was later also used for insulating the terminals of the base in place of wood. It was soon found that the tension created between the two terminals of the base when the lamp was firmly screwed in the socket often caused the base to pull apart, so the shape of the base was again changed in June, 1881, to the form in use today.

An improved method of fastening the ends of the filament to the platinum leading-in wires was adopted early in 1881. Formerly this was accomplished by a delicate clamp having a bolt and nut. The improvement consisted of copper plating the filament to the platinum leading-in wire.

Fig. 20
Original Screw Base—December, 1880

Fig. 21
Improved Screw Base—March, 1881

Fig. 22
Present Form of Screw Base—June, 1881

During the year about 34,000 lamps were sold, the list price being one dollar. They initially gave about sixteen candle-power, lasting about 3,000 hours before they burned out. The lamps blackened a great deal during their life, giving a very small part of their initial candle-power near the end of their life. They were first made for an efficiency of "eight lamps per horsepower." The term watts was unknown in those days. Each lamp consumed a little over 93 watts and, giving initially about 16 c-p. in a horizontal direction, hence had an initial efficiency of 5.86 watts per h-c-p. The reduction factor was about 80 per cent. This is mean horizontal candle-power in per cent of mean spherical candle-power, the latter being the average candle-power in all directions. The initial

efficiency expressed in the modern term of lumens per watt (one spherical candle-power equals 12.57 lumens) was therefore about 1.8 and the mean efficiency throughout life was about 1.3 lumens per watt.

In the fall of 1881 it was realized that this was an uneconomical efficiency. The efficiency was therefore changed to "ten lamps per horsepower" (4.66 w-p-h-c-p. or 2¼ l-p-w. initially), the lamps giving an average life of 900 hours to burn out. The present day 100-watt Edison MAZDA C lamp has an initial efficiency of 12.8 l-p-w. and a mean efficiency of 11.0 l-p-w. and if Edison's first

FIG. 23
Lamp of 1884

FIG. 24
Lamp of 1886

FIG. 25
Lamp of 1888

commercial lamp had been designed for this mean efficiency it would have given the same amount of light as the present 100-watt lamp but would have lasted only about one second. Another comparison is that the present 15-watt MAZDA B lamp gives on the average more light than Edison's original commercial lamp and consumes less than one sixth as much electric power.

Developments 1882 to 1888

The first central station generating current and selling it for general use was the Edison Electric Illuminating Company of New York, now The New York Edison Company. It started operations September 4, 1882, at 255 Pearl St., New York, with a load of about 400 lamps supplying some 85 buildings wired for 2300 lamps.

In the spring of 1882, the demand for lamps having outgrown the capacity of the factory at Menlo Park, manufacture was transferred

to a factory at Harrison, New Jersey, the present headquarters of the Edison lamp. None of the original buildings, however, are now standing.

In 1884 the ring of plaster around the top of the base was omitted. In 1886 copper plating the filament to the leading-in wires was abandoned, a carbon paste being substituted.

In 1888 the length of the base was increased so that it had more threads. The bamboo filament was improved by coating it with a hydro-carbon so that the efficiency was improved to 3.1 w-p-h-c-p. (3.5 l-p-w.). The lamp now consumed but 50 watts, and the maintenance of candle-power during the life of the lamp was much better.

Fig. 26
Lamp of 1892

Fig. 27
Lamp of 1894

Fig. 28
Lamp of 1900

Developments in 1893

Two Englishmen, Wynne and Powell, had invented a method of making a cellulose filament. This consisted of absorbent cotton dissolved in zinc chloride, the resulting syrup being squirted through a die into alcohol. The thread formed was washed in water, dried in the air, cut to proper length and carbonized. William E. Sawyer, one of the prominent Americans who had attempted to "subdivide the electric light" in 1878-9, had invented a process of coating a filament with graphitic carbon. This was done by heating the filament by the passage of current through it in an atmosphere of hydro-carbon vapor. The heat decomposed the vapor and deposited graphite on the filament, the process being called "treating."

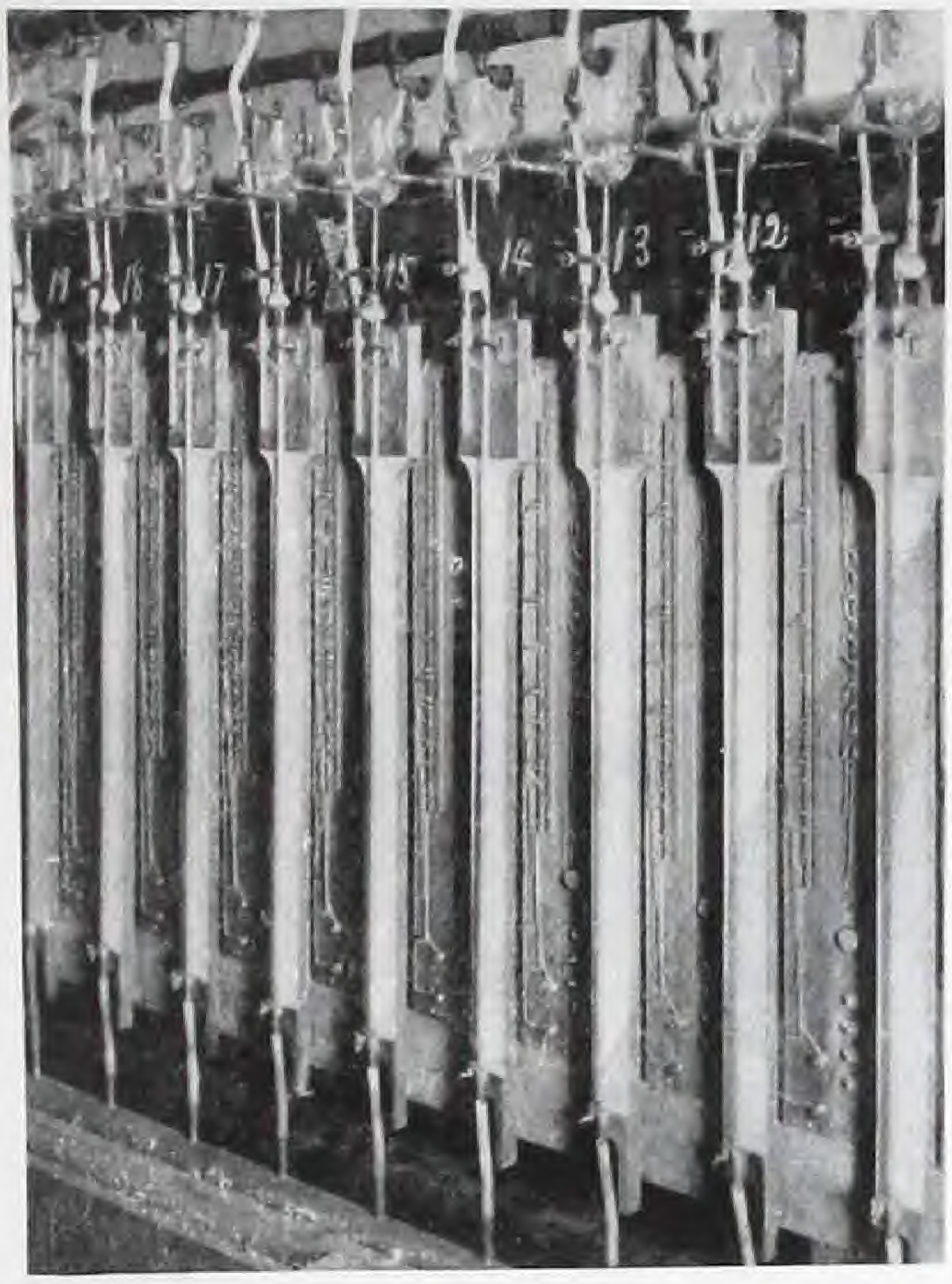

FIG. 29
Mercury Exhaust Pumps

The deposited graphite, having a lower specific resistance than the carbon core, required that the filament be longer for the proper resistance.

Up to this time lamps were exhausted by a mercury pump. Originally it had required eight hours to properly exhaust a lamp,

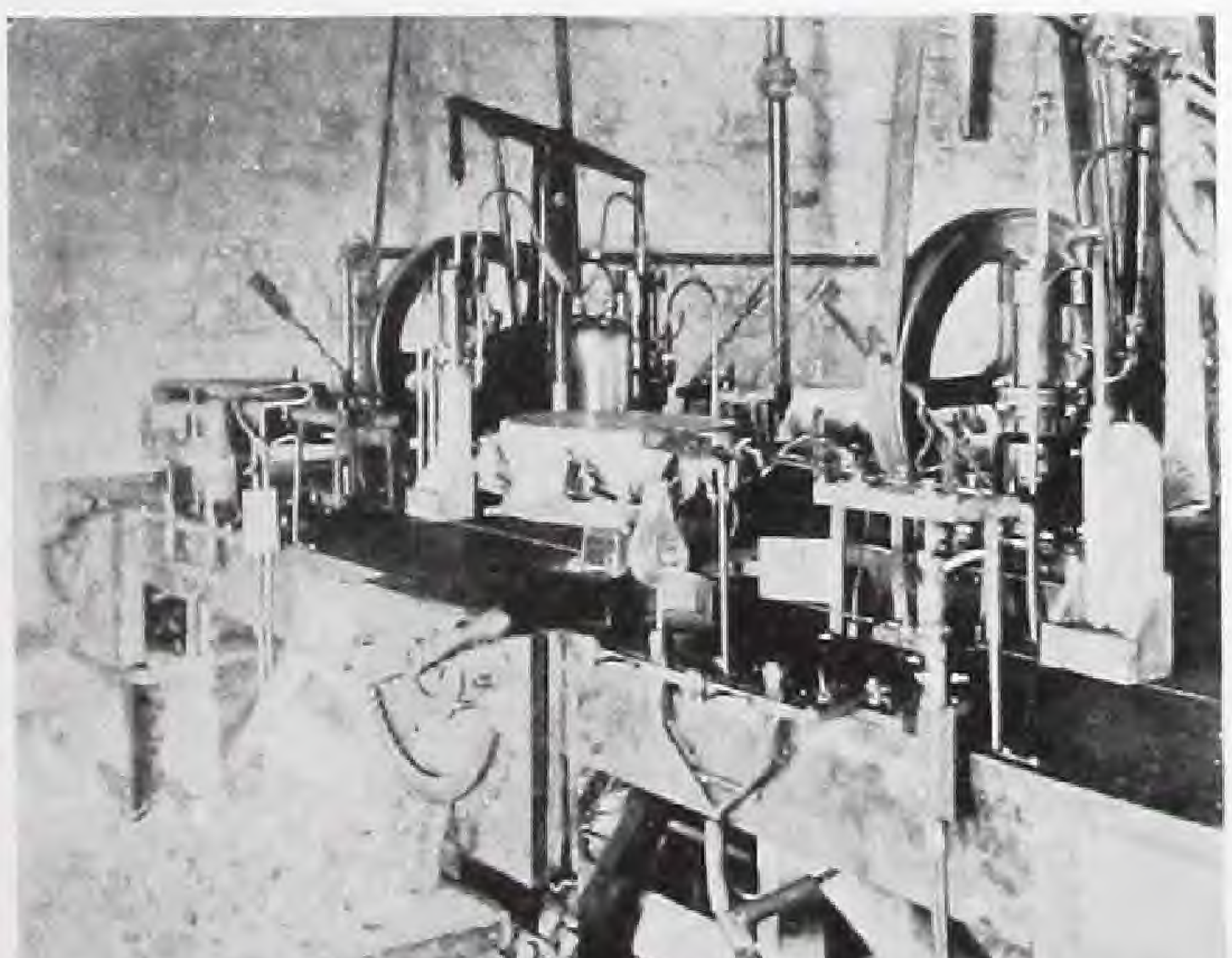

FIG. 30
Malignani Chemical Exhaust Process

but this time was soon reduced to about half an hour. The process was unsanitary as the operators were liable to mercurial poisoning.

Malignani, an Italian, invented a chemical means of improving the exhaust. This made possible the use of mechanical pumps to remove most of the air, the final traces, mostly water vapor, being removed by phosphorus. This process reduced the time of exhaust to less than one minute.

The carbon filament had now reached the highest stage of its development, excepting for the Gem or "metallized" carbon filament lamp, which was put on the market in 1905. The lamp still had the same efficiency as in 1888, but the maintenance of candle-power during the life of the lamp was greatly improved.

Fig. 31
Carbon Lamp of 1901

Fig. 32
Gem Lamp—1905

In 1894 bulbs were blown in moulds instead of in the open air and hence were more uniform in shape.

Plaster of paris used in the base prevented the lamp being used out doors. In 1900 porcelain was used for the insulating part of the base, which was fastened to the bulb by a waterproof cement. In 1901 glass was used instead of porcelain.

Gem Lamp

Dr. Whitney's experiments with carbon filaments in his electric resistance furnace at the Research Laboratories of the General Electric Company at Schenectady enabled him to produce a "metallized" carbon filament. Ordinary carbon has a negative temperature coefficient, that is, its resistance when hot is less than

when cold. The graphite coating on a treated carbon filament has a slightly positive temperature coefficient, but the treated filament as a whole has a negative temperature coefficient. Heating a treated carbon filament to the high temperature of the electric furnace greatly increased the positive temperature coefficient of the graphite coating, which changed the treated filament as a whole so that it then had a positive temperature coefficient, that is its hot resistance is greater than when cold. This is similar to metals, hence the expression "metallized" carbon filament.

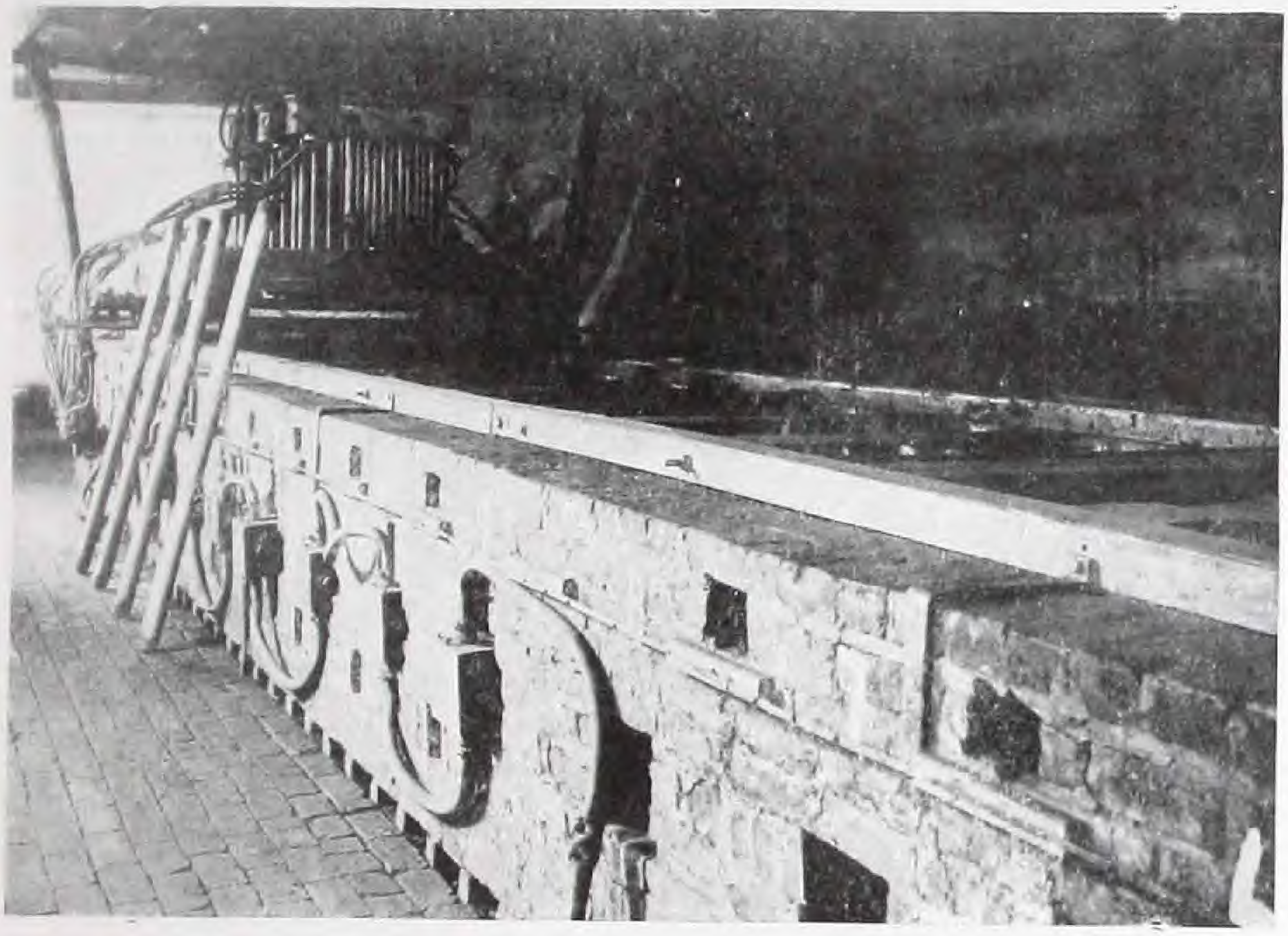

Fig. 33
Electric Resistance Furnaces

The trade mark Gem was adopted for the lamp, which when first put on the market in 1905 had two single hair pin filaments in series. In 1909 the Gem lamp was made with a single loop filament like the carbon lamp. It had an initial efficiency of 2.5 w-p-h-c-p. (4.0 l-p-w.) and a somewhat better maintenance of candle-power during its life than that of the carbon lamp, although it was not as rugged a lamp. It disappeared from the market in 1918.

Tantalum Lamp

Von Bolton in Europe invented the tantalum lamp. Tantalum is a metal, an element, and on account of its ductility can be drawn

out into a wire. Having a low specific resistance, the filament had to be much longer and thinner than in the carbon lamp. It had an initial efficiency of 2.0 w-p-h-c-p. (5.0 l-p-w.) and a maintenance of candle-power during its life about the same as that of the GEM lamp. It was not quite as rugged as the carbon lamp. On alternating current the life was somewhat shortened as then the wire crystallized and "offset" more rapidly so that it broke more easily. It was put on the American market by the General Electric Company in 1906 but disappeared in 1913. The lamp was first supplied with a skirted base as the neck of the bulb had to be very wide on account of the width of the mounted filament. Later on it became possible to melt down the neck, so an unskirted base could be used.

FIG. 34
Tantalum Lamp—1906

FIG. 35
GEM Lamp—1909

Tungsten Filament Lamp

Just and Hanaman, two Austrians, invented the tungsten filament lamp. Tungsten is also a metal, an element, and is extremely hard. Tungsten filaments were made by mixing finely divided tungsten powder with a binder into a paste and squirting the paste through a hole drilled in a diamond, forming a thread. Hair pin loops of this thread were treated to remove the binder and make what was called a pressed filament. Several hair pin loops were mounted in series to get the requisite resistance. The lamp was fragile but was a wonderful improvement as it could be operated at 1¼ w-p-h-c-p. (8 l-p-w.). It was put on the American market by the General Electric Company in 1907. The first

multiple lamp put out was the 100-watt size. Later it became possible to make finer filaments, so that lamps of 60, 40 and then 25 watts for 115-volt circuits were available.

After prolonged hearings in the Patent Office to determine who was the original and first inventor of the tungsten filament, a patent was granted February 27, 1912. This patent has been upheld in the courts.

Fig. 36
100-watt Pressed Tungsten Filament Lamp of 1907

Fig. 37
25-watt (Pressed Filament) Mazda Lamp of 1910

Fig. 38
Drawn Wire Mazda Lamp of 1911

Mazda Service

The trade mark Mazda was adopted late in 1909 as the mark of a co-operative service rendered by the Research Laboratories at Schenectady, which service consists of the obtaining of scientific and practical data from research laboratories, incandescent lamp laboratories and lamp factories all over the world, and transmitting to manufacturers entitled to receive this service such information as will enable them to improve the quality of their lamps.

The selection of the word Mazda as a trade mark was an extremely good one, because Persian mythology gives to their ancient god of light the name of Ahura Mazda, and as the Persian

light was knowledge, so the trade mark MAZDA of today stands for the accumulation and transmission of knowledge.

The filament of all MAZDA lamps at the present time is made of tungsten. When any material more suitable for the purpose is developed, lamps made using that material as the light source will be MAZDA lamps.

FIG. 39
MAZDA C Lamp, 1913

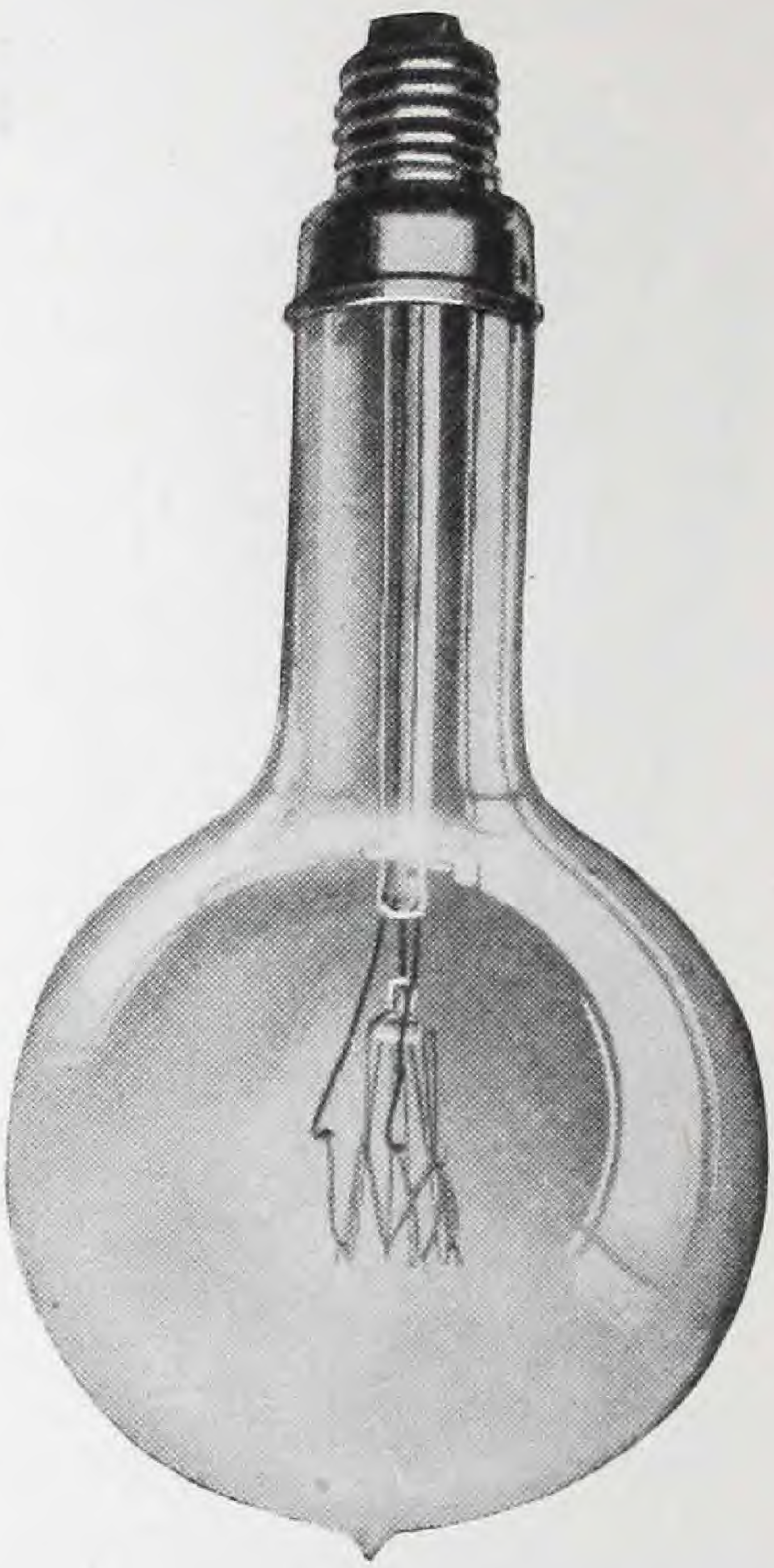

FIG. 40
MAZDA C Lamp, January, 1914

Drawn Tungsten Wire

Tungsten had always been known as a very brittle and extremely hard metal, and on account of its brittleness it was impossible to draw it out into a wire. Dr. Coolidge of the Research Laboratories of the General Electric Company discovered a process for making tungsten ductile. Very extensive commercial use of a continuous uniform filament of drawn ductile tungsten began in 1911. This greatly simplified the manufacture of the lamp and very mate-

rially increased its ruggedness. A patent was obtained December 30, 1913, which was involved in litigation and upheld.

Mazda C Lamps

The invention of Dr. Langmuir of the Research Laboratories of the General Electric Company made it possible to greatly in-

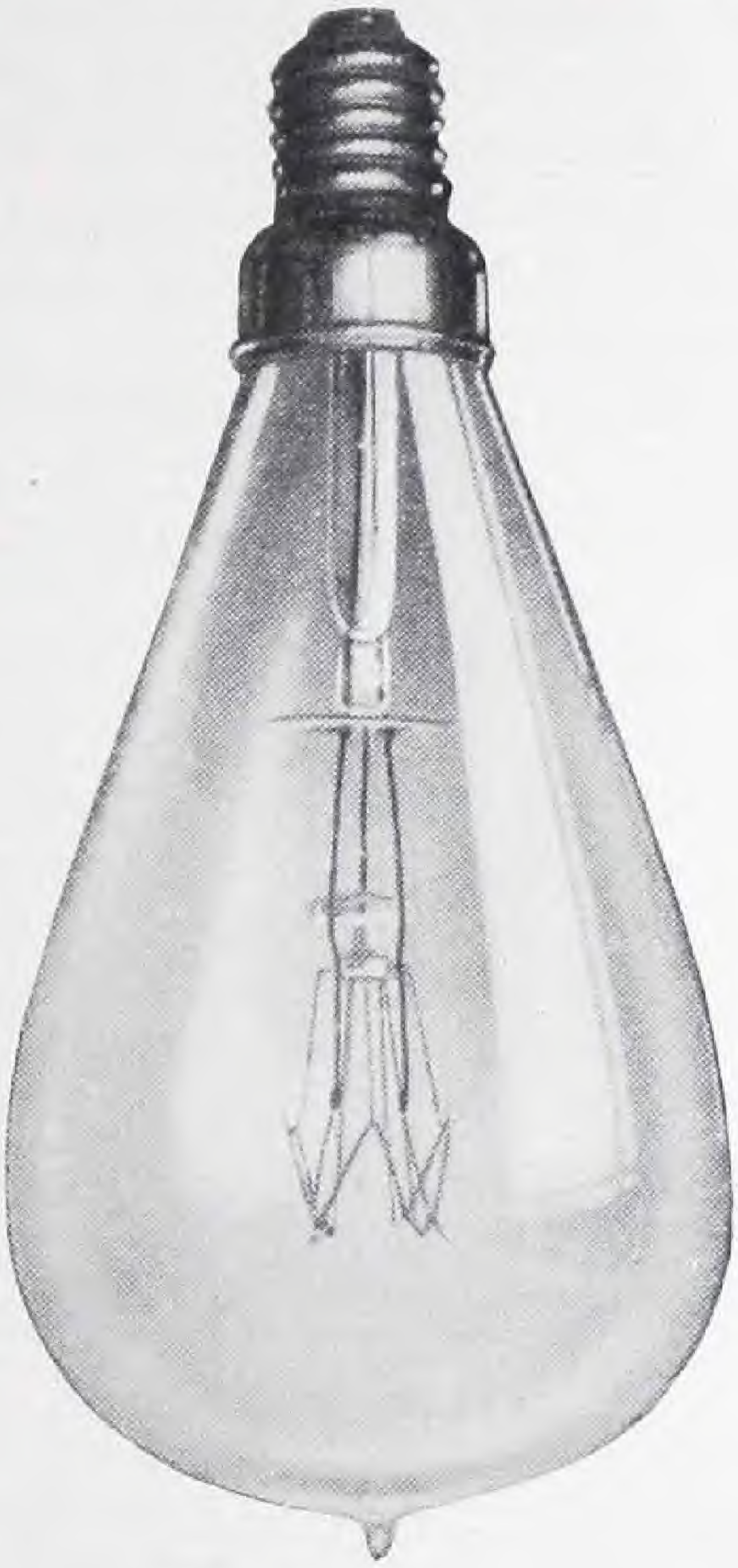

Fig. 41
Mazda C Lamp, July, 1914

crease the efficiency of Mazda lamps by the use of an inert gas in the bulb. This invention was used commercially as early as 1913. A patent was granted on April 18, 1916. This patent has also been upheld by the Courts.

At first these lamps were made only in large sizes, 750 and 1000 watts, nitrogen gas being used. They were called Mazda C lamps to distinguish them from Mazda B (vacuum) lamps. The latter, having drawn tungsten filaments, were called Mazda B lamps, as

if these designations had been used at the time that MAZDA lamps with pressed filaments were made, such pressed filament lamps would have been known as MAZDA A lamps. MAZDA C lamps were first put in round bulbs. Shortly after the introduction of these lamps a long glass neck was added to keep the base cool, and later a straight side bulb was used, a mica disk on the stem deflecting the circulating currents of gas away from the base. The efficiency of these lamps was about 20 lumens per watt or about 2½ times that of the original tungsten filament lamp. Another comparison would be that if the original tunsten filament lamp had been designed to operate at this efficiency, it would have lasted but about an hour and a half.

During the latter part of the year 1914 a 500-watt MAZDA C lamp for 115-volt circuits was made and towards the end of the year, 300- and 200-watt lamps were developed.

Recent Developments in Leading-in Wires and Getters

Platinum had long been used as the leading-in wire, going through the glass to connect the filament inside the bulb with the circuit outside, because it has about the same coefficient of expansion as glass and makes a good tight joint when sealed in the glass. The invention of copper coated nickel-iron wire, called "Dumet" wire, a patent for which was granted May 18, 1915, made it possible to give up the use of platinum, which otherwise would have been a very serious matter during the war as the supply of platinum became extremely limited. This "Dumet" wire is even better than platinum as a leading-in wire, and was in very extensive commercial use by the early part of 1914.

About 1915 certain chemicals were put inside the bulb of MAZDA B lamps, which greatly improved the maintenance of candle-power of the lamps during their life. These chemicals, known as "getters," retard the blackening of the bulb, the effect being less on the lower wattage lamps as the filaments of such lamps being thinner, there is less tungsten to evaporate and blacken the bulb before the filament ruptures. As a result there was a considerable improvement in efficiency and maintenance of candle-power.

Present MAZDA C Lamps

In 1915 MAZDA C lamp bulbs were changed to pear shape. A 100-watt lamp for 115-volt circuits was standardized, which had argon instead of nitrogen gas in the bulb. Argon is an element

and is one of the constituents of the air, being present, however, in small quantities, less than one per cent. It has a poorer heat conductivity than nitrogen thereby reducing the convection losses of the lamp which becomes of increasing importance the lower the wattage of the lamp.

Fig. 42
Present Mazda C Lamp

In 1916 a 75-watt Mazda C lamp was standardized and in 1919 a 50-watt Mazda C lamp was developed. Today (1922) there are Mazda C lamps available from 50 to 1000 watts for 115-volt circuits. Gas filled lamps of less than 50 watts for 115-volt circuits have at present no greater efficiency than it is possible to attain with Mazda B lamps.

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